Executive Summary

of the

CLOUD IMPACTS ON DOD OPERATIONS AND SYSTEMS - 1988 WORKSHOP (CIDOS - 88)

18–20 October 1988

Naval Surface Warfare Center

White Oak, Silver Spring, Maryland

COVER Clouds over the Great Salt Lake Basin - an example of the complexity of satellite cloud detection.

The image is photography #358 from the Large Format Camera (LFC) on board the space shuttle mission 41-G, October 1984. North is located along the 45° diagonal directed from bottom right to top left. The photograph was taken at 14:04:14 MST (21:04:14 UT), 6 October 1984, from an orbital height of 265.92 km above mean sea level, approximately 264.6 km above the surface of the Great Salt Lake. The center of the image is a 41.09N, 112.17W. The solar elevation angle is 37.5°. The total distance across the image, top-to-bottom or vice versa, is approximately 154 km, from which a scale factor can readily be computed.

The Large Format Camera is primarily a cartographic instrument of great geometric fidelity and extraordinary coverage. Although not designed for the purpose of cloud depiction, the high resolution and exceptional stereographic capabilities of the LFC allow the specification of the horizontal and vertical coordinates of any identifiable cloud element to $\pm$ 20 m. The film used for photograph #358 was Kodak #3414, High Definition Aerial Film, an extremely fine-grain monochromatic emulsion having extended red range. The maximum sensitivity is between 0.65 and 0.70 μm. The photography is therefore comparable to an image produced by a high resolution, single channel radiometric scanner operating within this wavelength band.

Cumulus humilis and mediocris are scattered over the Wasatch Range, east of the Great Salt Lake, and over the southern escarpment of the Uinta Mountains (top right corner). The simple threshold-brightness technique for cloud/no-cloud determination would likely classify much of the Duchesne Valley (extreme top right edge) as cloudy rather than its actual cloud condition, totally clear. The turbid Utah Lake, south-southeast of the Great Salt Lake, might also be classified as cloudy by this technique and certainly the highly reflective Great Salt Desert (bottom center of back cover) would be interpreted as overcast, rather than clear.

Cirrus fibratus, much of it semi-transparent in the red portion of the visible spectrum and viewed at near nadir, is occurring in a north-south band from the vicinity of Pocatello, Idaho (beyond top edge near center of back cover) down across the center of the Great Salt Lake and southward to the lower center edge of the image (near centerfold). To distinguish this thin cirrus from the underlying cumulus and/or very reflective surfaces is indeed difficult, especially where the cirrus is thick enough to preclude cumulus shadows, for example in the vicinity of Malad City, Idaho (somewhat below top edge near center on back cover). Coastal turbidity and turbidity streaks, prevalent in the western portion of the Great Salt Lake, are also difficult to distinguish from cirrus. However, more knowledge-based techniques in the region, where, fortuitously, a few puffs of cumulus cast distinct shadows on the turbid coastal water confirm the presence of turbid water and not cirrus clouds. Examples of such telltale shadows are found on the northwestern coasts of the Great Salt Lake and Utah Lake. What percent of the entire image is cloud covered?

J. William Snow

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Executive Summary of the Workshop on
CLOUD IMPACTS ON DOD OPERATIONS AND SYSTEMS
Convened at the Naval Surface Warfare Center, White Oak, MD
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PREFACE

This document constitutes the Executive Summary of the Cloud Impacts on DoD Operations and Systems 1988 Workshop (CIDOS-88) held at the Naval Surface Warfare Center, White Oak, Silver Spring, Maryland on 18-20 October 1988. It is distributed primarily to the CIDOS mailing list which contains approximately 450 addressees. A companion document, the detailed proceedings of CIDOS-88 to be published later, will receive a more limited distribution, specifically to the CIDOS-88 attendees. The purpose of this Executive Summary is to expeditiously inform the entire DoD cloud impacts community, i.e., decision-makers, systems developers, program managers, and environmental researchers, of the purpose, presentations, discussions, and conclusions of CIDOS-88.

CIDOS-88 was the sixth formal meeting of the DoD cloud impacts community, which first convened in 1983 using the name Tri-Service Clouds Modeling Workshop. In mid-April 1988, the Steering Committee and invited spokesmen for various DoD environmental impacts/issues directorates held a day-long meeting to re-examine the function and relevance of our community and to resolve specific questions regarding this year's meeting. It was universally concluded that the name of our group conveyed a too restrictive and/or ambiguous meaning to our true purpose. The community name was therefore, changed from "Tri-Service Clouds Modeling" to "Cloud Impacts on DoD Operations and Systems" (which carries the acronym CIDOS). Reaffirmed at the Steering Committee meeting was our charter, namely to assist DoD regarding cloud issues. The orientation of our efforts must be the user, systems and operations agencies of DoD having problems caused by clouds in the atmosphere. Our primary purpose is the application of the atmospheric sciences to evaluate the impacts of clouds on weapon and sensor systems and military operations and to recommend procedures for exploiting or mitigating those effects. These were the policy decisions made at the April meeting.

A restructuring of our annual meeting was also decided upon at the Steering Committee meeting. The following elements were explicity called for: i) formal poster/ demonstration presentations, ii) specific topical workshop sessions, iii) a plenary session for presentation of topical workshop results, iv) a session to address the effects of strategic weapons deployment on cloud environments, and v) an Executive Committee meeting. This Executive Summary is a digest of the workshop meetings and of the Executive Committee meeting.

Gratefully acknowledged is the support and cooperation of all session chairs and presenters during CIDOS-88 and in the preparation of this Executive Summary and the forthcoming proceedings. A special expression of thanks is extended to Science and Technology Corporation for coordinating the various meetings and activities preparatory to CIDOS-88. The superlative efforts of the Meetings and Publicaton Divisions of Science and Technology Corporation are sincerely appreciated.

Donald D. Grantham
J. William Snow
December 1988

PART 1. EXECUTIVE STATEMENT

CLOUD IMPACTS ON DEFENSE SYSTEMS

Col Ted S. Cress
OUSDA (R&AT/ELS)

The following is a quote from a 1982 memorandum prepared by the then Military Assistant for Environmental Sciences, OUSDA (R&AT), Col Paul Try, which was sent to the Directors of several DoD research laboratories. "We have worked very hard to obtain recognition of the weather effects by the operational evaluation community; however, now that we have achieved this recognition, we are failing to produce even the most basic binary cloud data and methodologies needed to support the evaluation programs. We need to.....resolve some of the recurring issues in cloud modeling." That memorandum has become the reason for existence of the cloud impacts community. The above quote, in addition to encapsulating the state of affairs at the time, highlights the community's major shortcomings.

The recognition Col Try referred to is not fully codified. While addressed in part by certain service regulations, OSD guidelines for test and evaluation of systems under development do not require any assessment of environmental impacts or limitations. Service guidelines typically require inclusion of environmental considerations only well into the operational testing of systems rather than from the very outset of the development process where the greatest impact could be made. Success, including adequate considerations of environmental limitations to proposed systems, still resides with the individual environmental people assigned to support particular development programs.

The clouds issue is an excellent example of an environmental problem that is recognized by the atmospheric sciences community, that has some impacts assessment methodologies developed, and that is marketed to systems developers and users. In 1982, the Air Force Geophysics Laboratory was identified as the proper organization to lead efforts toward the resolution of cloud-related problems. Army and Navy research activities were identified to assist in the planning for the overall effort. The tasks laid out at that time were:

(1) To identify key issues, scope the efforts involved, and determine the appropriate agencies to work each task;

(2) To provide the continuity needed to assure eventual solution.

In this context, "continuity" was meant to include not only funded efforts, but also information exchange and the development of a "corporate memory." A nascent program called CLOUDS, the acronym for Cloud Logic to Optimize Use of Defense Systems, was

developed with these two tasks in mind. During its first two years, CLOUDS had limited effectiveness, not due to lack of enthusiasm but due to scarce resources. The Space Defense Initiative (especially Directed Energy and Innovative Science and Technology) has been a boon to the funding of needed efforts. This conference serves the requirement for information exchange and sharing. But what is still missing is a single source of model and data base information to which the developer can routinely go for help in understanding how and why the environment will limit what he is trying to develop, how to mitigate those impacts, and to find out if options are available. This is the real payoff for the CLOUDS program.

The "recognition" referred to by Col Try was real. It takes many forms--from greater visibility, due to the concerted effort of the research community and its interaction with the developers, to greater coherence within our community itself. Also, his reference was to the recognition of modern forecasting capabilities. That is the acknowledgment by decision-makers and technical experts involved in system design and development that the atmospheric sciences have matured to the point where they can produce more than an occasionally correct weather forecast. It is certainly possible to specify certain atmospheric parameters explicitly for systems evaluation, for example transmission loss and contrast reduction at virtually any wavelength as a function of moisture or aerosol concentration. What cannot yet be done is to specify radiational atmospheric conditions at particular target areas in real time--that capability, now under development, is vitally needed. Cloud impacts and specifications are being worked; this conference is the periodic update on those efforts.

Substantial activity has transpired since that 1982 beginning. This is, for example, the sixth of these workshop conferences. Also numerous smaller meetings have been held--all with the purpose of putting teeth into our original claim that we could help the military systems designer and operations planner. Has this community proven that claim? What has been accomplished? Are we now able, or on the verge of being able, as Col Try put it, to "produce even the most basic binary cloud data and impacts evaluation methodologies?" The answer is, at best, a mix. The presentations being made here are testimony to a high level of activity and serve to document the progress that has been made.

The progress we have seen, however, falls far short of the anticipation of 1982. We have a long way to go to meet the initial objectives that were envisioned in the original CLOUDS program. We promised a comprehensive package of data bases and methodologies, but we have not created a consolidated cohesive package that the evaluation community can pick up, utilize, and appreciate. We have not convinced the evaluation community that what has been accomplished is significantly important to them and usable by them. In addition to the first rate science being done, we need to deliberately design, develop, and produce products from the CLOUDS program in a manner that makes them easily obtainable, understandable, and usable by the development/evaluation community. That we have not done well.

On the positive side, there are some significant goals that have been attained and products that are being used. Examples of these are the following: Certain digital cloud

data bases are now available. Superior retrieval methods for satellite cloud information are gradually becoming operational. Impact assessment methodologies are improving because more representative, site-specific, and cloud-type specific cloud-free line-of-sight models are becoming available. The stochastic approach to assessment is powerful, since it can synthesize realistic cloud scenarios with incredible speed and relative low cost. We are gradually getting to the point where we can address the accuracy of such approaches to impact assessments, and one SDI project is currently doing just that. But, even these are limited successes and, individually, they are a piecemeal approach to the overall problem.

To reiterate, we are making progress, but we have a lot to do. The Steering Committee has made an effort to focus goals on the needs of the respective Services and to improve necessary communication links and channels. The orientation of these efforts must be the user, specifically the systems development and operational agencies that have potential or real problems caused by clouds. This conference will take on the additional aspect of working groups to define those cloud-related needs and identify potential research efforts that can be brought to bear on solutions. With this expanded character, the Steering Committee has adopted a new name that better describes our mission--Cloud Impacts on DoD Operations and Systems, CIDOS, for short.

I urge each of you to whole heartedly adopt this approach; identify the critical cloud-related problems, and produce the necessary use-oriented solutions. In the near term, let us each help to make CIDOS-88 an unqualified success.

PART 2. WORKSHOP SESSION SUMMARIES

INTRODUCTION

A significant element in the restructuring of the Tri-Service cloud impacts community is the inclusion of actual workshop sessions within our periodic meetings. The functions of each workshop are:

(1) Assess the present state of affairs with its topic area;

(2) Identify critical issues and deficiencies;

(3) Develop strategies for resolving the issues and eliminating the deficiencies;

(4) Specify techniques, methods, organizations or agents best suited to address the problem areas and;

(5) Report on its deliberations and conclusions.

Function (5) is fulfilled in this part of the Executive Summary. Session topics and chairs are first listed, then follow the workshop summaries as presented by the chairs at the Plenary Session.

LISTING OF WORKSHOPS AND CHAIRS

I. CLOUD IMPACTS ON SURVEILLANCE, STUDIES AND ANALYSIS, AND THE POST-ATTACK ENVIRONMENT

Co-Chairs: Col J. D. Mill, SDIO/SN
Dr. G. W. Ullrich, DNA
Dr. F. E. Niles, ASL

II. HIGH ENERGY LASER-CLOUD INTERACTIONS

Co-Chairs: LCDR J. P. Garner, SDIO/DE
Dr. D. D. Smith, Aerospace

III. CIRRUS CLOUDS AND LIDAR DETECTION OF CLOUDS

Co-Chairs: Lt Col K. E. Eis, AFSC/WER
Dr. P. F. Twitchell, ONR

IV. CLOUD MODELING, PREDICTION, DATA BASES

Co-Chairs: Lt Col R. C. Whiton, HQ AWS
Dr. J. W. Snow, AFGL

Summary of Workshop I

CLOUD IMPACTS ON SURVEILLANCE, STUDIES AND ANALYSIS, AND THE POST-ATTACK ENVIRONMENT

Co-Chairs
Col John D. Mill
Dr. G. Wayne Ullrich
Dr. Frank E. Niles

Not surprisingly, the overall conclusions of this workshop were that much has been accomplished, yet much remains to be done. It is encouraging that many system designers/developers are taking the effects of the natural environment into account in much more realistic ways; they are, in fact, funding studies of the effects of the environment on their systems. Examples include Infrared Search and Track (IRST), the Airborne Optical Adjunct (AOA), and the SDIO Strategic Scene Generator (SSG) effort. There also appears to be closer cooperation and increased synergism between DoD and other government research programs. The prime example in this community is the effort to better understand the environmental effects of large fires. There are increasing levels of interchange among the R&D, development, and operations communities.

But more needs to be done. The research community must become more involved with helping the operators develop tactics and not concentrate on just assisting the development community. Typically, a system concept starts with an operator's requirement, and injecting concern for environmental effects at this point holds the promise of addressing environmental concerns in the concept definition phase, as opposed to the usual practice of incorporating them only as an "after-thought." It still seems desirable to somehow institutionalize the consideration of environmental effects into the requirements and development processes, but it is not clear how that can be done effectively. A necessary first step is to document updated realistic statements of requirements for the observation and forecasting of clouds in support of developing systems.

The workshop reached several conclusions in the three areas that were within its responsibility. It quickly became obvious that thin or "subvisible" cirrus has become an important issue, and will likely continue to increase in importance over the next few years. Of overriding importance, at least within the areas of concern to this workshop is the impact of thin cirrus, as well as other high-altitude clouds, on surveillance. It affects space-based surveillance of the earth limb as well as high altitude air-to-air and

air-to-space platforms, Fortunately, it is also apparent that a great deal of progress has been made in understanding the microphysics of cirrus as well as its morphology; more, however is needed.

As surveillance systems become more capable and more sophisticated, knowledge of the effects of clouds as background clutter becomes an increasingly stressing factor on performance. Systems will operate at ever increasing sensitivities, higher spatial and temporal resolution, and at wavelengths (principally the UV) not heretofore considered important. The knowledge of backgrounds, including clouds, at these increasing sensitivities and resolutions, must keep pace. On the plus side, scene generation or simulation techniques are becoming more realistic and efforts are underway to develop comprehensive scene generators for both strategic and tactical applications.

Concerning manmade clouds (including smoke and dust), considerable progress has also been made in understanding the effects of large fires. The dynamics of individual plumes is well understood and realistic, flexible models exist. More work is needed on the microphysics of induced clouds and on models of atmospheric response to multiple fires and other manmade effects of regional- and theater-scale conflicts. Emerging mesoscale weather codes offer a near-to-mid-term promise of providing a useful framework for these interactions. Well-planned, cooperative, fully characterized field experiments on large fires are also needed to validate the models. In the related area of battlefield obscurants, there is a good qualitative understanding of the effects of smokes and battlefield-induced contaminants near the FEBA, but more quantitative data are needed, and attention must be paid to wide-area screening of rear echelons and its effect on the Follow-on Forces Attack doctrine and top attack weapons.

Finally in the area of tools and data bases, there are some near-term actions that will enhance the effectiveness and the efficiency of studies of cloud impacts. Procedures should be developed, and widely publicized, for saving volatile data (such as high-resolution DMSP data) that will be needed for the future analysis of unexpected events such as large natural fires or unusual occurrences of high-altitude clouds. A set of reference clouds (both natural and manmade) is needed so that future simulations and other modeling work will be more easily and directly comparable and design trade-offs will be more consistently executed. This model set will also serve to enhance technology transfer from the research community to systems developers, operations researchers, and operators. As such it is a logical first step in the development of a more systematic approach to technology transfer. Such a systematic approach might conceivably be a data repository, a technique development organization, a more pro-active technologist/ engineer/ planner/ operator interface, or some combination of all three. The need has existed for a long time and is becoming more critical as systems become more sensitive to the environment. Now is the time to start moving systematically toward the goal.

Summary of Workshop II

HIGH ENERGY LASER-CLOUD INTERACTIONS

Co-Chairs:
LCDR Janice P. Garner
Dr. Duane D. Smith

DoD NEEDS

The two principal motivations for the DoD high energy laser-cloud clearing impact assessment are the following: (1) to determine if laser cloud-clearing can lower the overall ground-based laser (GBL) system cost by reducing the number of GBL sites that would otherwise be needed to maintain the required GBL availability under cloudy conditions without cloud-clearing, and (2) to determine if laser cloud-clearing can mitigate strategic weaknesses arising from enemy exploitation of cloud obscuration of GBL sites. A reliable assessment of cloud-clearing impacts on the GBL system requires cost estimates of a cloud-clearing laser system and data on what types of clouds would need to be cleared over the GBL sites. A reliable impact assessment also requires data on the types of clouds for which clearing lasers can reduce the absorption and scattering losses to acceptable levels while maintaining a level of residual optical aberrations in the hole that is small enough to allow wavefront reconstruction through adaptive optics.

TECHNOLOGY AND/OR INFORMATION SHORTFALLS: POTENTIAL SOLUTIONS

1. **There is a data shortfall on internal cloud properties and probabilities of occurrence that are germane to cloud clearing.** To assess the utility of laser cloud-clearing, it is essential to know the index of refraction fluctuations within the cloud prior to clearing. If the internal optical turbulence is severe prior to laser-induced clearing, and if clearing produces no additional optical turbulence, then even though transmission losses through the hole have been reduced by clearing, it may not be possible to reconstruct wavefronts that have passed through the hole. There is also a need to know the cloud internal wind velocity fields, because the wind determines the amount of new, unvaporized material being swept into the beam. The wind will therefore influence the clearing laser power requirements and the time evolution of the hole. The probability of multilayer clouds is also important in that different clouds types at different altitudes with different directions of motion may alter the efficacy and the optimum method of cloud-clearing. The cloud internal composition (ice and liquid water content) will influence the power requirements as well as the recondensation and post-clearing propagation effects. Cloud-internal nucleation center densities and identities are needed to assess the probabilities for recondensation. All of the internal cloud data are also needed for nighttime clouds. Conducting further synoptic meteorology surveys will not help alleviate these

information shortfalls; lidar measurements and in situ cloud microphysical data are required.

2. **There is a paucity of relevant subscale laboratory and field simulations.** Simulations of laser-cloud clearing have yet to measure the residual optical aberrations in a cleared hole. Laboratory laser cloud-clearing simulations also need to establish the laser wavelengths that are optimum for cloud-clearing and propagation through the holes. The laboratory and field simulations need to use realistic drop and crustal size distributions and densities. Ambient atmospheric conditions in the cloud chamber and the field as well as the laser parameters need to be well-diagnosed and realistic. Attention to scalability of the laboratory and field results cannot be over-emphasized. Laboratory simulations offer a way to control cloud parameters that cannot be arranged for in field measurements. For example, drop sizes, ambient temperature, wind, cloud composition, and other cloud parameters can be modified upon demand and studied in an accelerated fashion. Field and laboratory experiments need to be coordinated. Field subscale tests need to be well instrumented with meteorological data acquisition and optical probing of the cleared hole.

3. **Predictive models need data input on microphysical processes in cloud nucleation and evaporation. Models of optical propagation through laser-cleared holes need to include nonlinear distortions and residual optical aberration.** Evaporation and sticking coefficients for water molecules on clean and dirty ice water are critical parameters in predictive modeling of laser cloud-clearing. The evaporation and sticking coefficients are essential to model the evaporation process, calculate clearing laser power requirements, and to calculate recondensation rates. These coefficients presently vary by factors of 10, whereas errors of 10's of percent are needed. Acquisition of accurate sticking coefficient data requires well-designed single- and many-body evaporation/recondensation measurements. Accurate sticking coefficients are also essential input to upcoming models of laser cloud-clearing that will use molecular dynamics calculations. The molecular dynamics calculations have not been used in laser cloud-clearing before and, given accurate enough sticking coefficients as input, they should offer unprecedented detail and accuracy. Predictive models need further development to include the effects of thermal blooming and nonlinear beam distortions.

In summary, the basic physics issues surrounding laser cloud-clearing are still being investigated. There is no directly applicable U.S.A. laboratory cloud-clearing simulation data available. A bottleneck in predictive models has emerged due to the lack of accurate evaporation and sticking coefficients for water and ice. Moreover, models are unable to calculate optical aberrations and distortions in the cleared hole that are either linear or nonlinear in the clearing laser power. The near-term effort should be to establish stepwise, application-oriented simulations of laser-cloud clearing that use meteorological

data relevant to CONUS GBL sites. By coupling the simulation measurements with improved models, the program will develop enough data and predictive modeling to support a system-level decision on the utility of laser cloud-clearing.

Summary of Workshop III

CIRRUS CLOUDS AND LIDAR DETECTION OF CLOUDS

Co-Chairs:
Lt Col Kenneth E. Eis
Dr. Paul F. Twitchell

The session and subsequent workshop on cirrus clouds was dominated by a single realization -- we actually know less about cirrus cloud climatology, structure, morphology, and forecasting than was generally believed 5 years ago. It was pointed out that the realization results from the analysis of lidar measurements. Fortunately, the recognition of the problem is also the beginning of a better cirrus cloud understanding. Lidar measurements identified the problem and lidar will help to solve it.

From a military perspective, the new understanding of cirrus clouds needs to be exploited to better support military systems. The workshop session identified several military systems' sensitivities not addressed by the conference. These included abrasion of composite materials and sensor shields by cirrus ice particles, cirrus electrification processes, conditions that can induce lightning strikes on aircraft and missiles, and contrail forecasting. These issues and the problems identified during the sessions, such as radiance specification, transmissivity, background characterization, subvisual cirrus, and basic cirrus forecasting and observation can best be resolved with more extensive and frequent lidar measurements.

The overall opinion of the conferees is that DoD should work with the research community in funding lidar instruments to establish a global cirrus data base derived from lidar and other measurements, which would include subvisual cirrus. Both communities should explore alternate methods of observing subvisual cirrus and cirrus overlaying lower clouds. DoD should begin by establishing long-term lidar measurements at its test ranges to supplement the intensive data collection carried out by researchers such as during the FIRE field program.

A number of the presentations made in Session IV and Session VIII of CIDOS-88, pointed out how inadequate cirrus climatology and incomplete information on atmospheric transmission impact military sensors and operations. CIDOS should remain focused on these key issues.

Recommendations for the near term are the following: (1) merge inputs from the military sensors community and the community of staff meteorologists, and (2) develop a plan of attack for funding lidar instrumentation, measurements, and data analysis.

Summary of Workshop IV

CLOUD MODELING, PREDICTION, DATA BASES

Co-Chairs:
Lt Col Roger C. Whiton
Dr. J. William Snow

This workshop included most of the material emphasized in the previous formal meetings of the DoD cloud community. The participants, approximately 35 researchers, practitioners, and administrators, were asked to write down the most frequently occurring cloud issues and/or cloud-related problems they encounter in their day-to-day work environment. The six topics, which encompass the responses, are here detailed. Also, as a summary, the six problem/solution vu-graphs presented during the Plenary Session on 20 October 1988 are included for the record.

Two topics, (1) cloud detection and (2) cloud forecasting, comprised nearly half of all responses. The need for precise specification of clouds using present or planned environmental satellites is pervasive. The problem is especially acute in regard to thin and subvisual cirrus and for clouds overlaying snow/ice background. Improved satellite cloud detection algorithms, better horizontal resolution, and proper vertical positioning of clouds--these specific items were identified under topic (1) as major needs.

Improved cloud forecasting capability (topic 2), especially over a relatively short timeline (specifically <12 hours), was identified as a present and foreseen operational problem. The scale of this forecast requirement is perceived as global. Fundamental to such forecasting is proper initial conditions, meaning topic (1) is reemphasized. A specific question requiring resolution is: Where on the forecast timeline does the simple persistence/trajectory technique break down? It is, of course, recognized that a more physics-based forecast scheme is needed for operational forecast products farther out on the forecast timeline. Even the forecasting of the conditions conducive to cirrus formation and of the radiative properties of these clouds are especially critical issues under topic (2).

Topic (3) was cloud data bases. A widely perceived need in the clouds community is that of an annotated index of cloud data bases, which includes short descriptive summaries of the type, duration, and accuracy of each data set. Closely allied and therefore included under this topic is the lack of realistic cloud-background (clutter) data sets. It was pointed out that the lack of a readily available compendium of cloud data bases was instrumental in the establishment of the DoD cloud community nearly 6 years ago and, in truth, not a great deal of organized progress in rectifying that need has been made to date.

Another identified need was an accepted validation procedure for cloud models, topic (4). Once a model has been so validated, then it can with confidence be applied in engagement and systems effectiveness studies and analyses. In fact, it was suggested that validated high-quality and versatile cloud models be made standards against which proposed systems and operations that are affected by clouds must be exercised.

The two remaining topics concerned the quantification of clouds in terms directly useful to impacts assessments. These were (5) spatial characterization and (6) microphysical characterization of clouds. Topic (5) includes the probability of cloud-free lines and arcs as a function of elevation angle and analytical expressions for clear internal lengths, both of these by cloud amount and cloud type. Topic (6) is motivated by relatively new weapons concepts. In one case there is renewed concern with cloud particulate erosion of hyper-mach reentering vehicles and non-metallic airfoils. In another scenario the microphysical details of clouds, especially cirrus clouds, must be known if the capability to effect clearing as an enhancement to ground-based laser utility is to be realized.

Cutting across all six identified topics was the specific consideration of cirrus clouds in regard to each. Cirrus cloud detection, forecasting, data base development, modeling, and taxonomic and microphysical specifications are all critical issues.

As a summary of Workshop IV, the vu-graphs in problem/solution format used during the CIDOS-88 Plenary Session are included. With these an attempt is made to address, in order, the six topics most frequently noted (in written form) during Workshop IV. However, the vu-graphs reflect most directly the content and extent of oral discussion. Therefore some change in emphasis (some additions or deletions) from the synopsis given above is present. It is hoped that these six problem/solution sets contain the distilled essence of the Workshop IV verbal exchange.

1. **Problem:** IMPROVEMENT OF CLOUD ANALYSIS ($t=0$) AND PREDICTION ($0<t<12h$) - including the cirrus analysis and prediction problem

   Solution: Identify user need

   Describe existing capabilities

   Understand technology shortfalls

   Develop recommendations for R&D

   Resolve where different approaches (kinematic, cloud physics, statistical) are most useful along the forecast timeline

   Consider modeling being done throughout the meteorological and other scientific communities

2. **Problem:** CLOUD DATA BASES - Climatology, clutter/background, thickness, radiative characteristics, microphysics, optical depth, spatial and temporal characterization

   Solution: Data base of data bases. Index including descriptive summaries, location, accessibility, length of record, and quality of data sets

   Reference data sets

3. **Problem:** VALIDATED CLOUD MODELS - for studies, analyses, simulations

   Solution: Taxonomic classification scheme developed

   Existing physical and statistical models categorized and described

   Validation methodology developed, models validated using approved method

   DoD handbook of cloud models

4. **Problem:** CIRRUS, ESPECIALLY THIN AND SUBVISUAL CIRRUS - detection, description, prognosis

   Solution: Research cirrus cloud physics

   Extensive lidar measurements and analyses

   Development of analysis (especially using satellite data) and forecast models

5. **Problem:** DATA SETS INTERCOMPARISON

   Solution: Utilize fully present detection capabilities especially multispectral, high resolution satellite imagery

   Satellite/Whole-Sky Imager (WSI), WSI/Lidar, WSI/Shuttle Series

6. **Problem:** PHYSICS-BASED CLOUD CATEGORIZATION

   Solution: Description of clouds in terms of their microphysical and radiative characteristics, specifically particle size distribution, attenuation, emissivity

   Relate to traditional cloud typing

PART 3. EXECUTIVE COMMITTEE MEETING REPORT

The restructuring of the DoD Cloud Impacts Conference resulting from its Steering Committee meeting in April 1988 provides for an Executive Committee meeting. Attendees at this session are designated representatives of DoD agencies that have cloud impacts concerns and all session chairs from the CIDOS conference. Here, in summary form, are presented the items discussed during the 20 October 1988 committee meeting.

1. **Community.** The dominance by Air Force personnel and its contractors in the CIDOS community continues, but the increased active participation of the Army, especially Atmospheric Science Lab (ASL) and the Navy, in particular the Naval Surface Warfare Center (NSWC), Office of Naval Research (ONR), and the Naval Environment Prediction Research Facility (NEPRF), is encouraging. The very substantial support of the Strategic Defense Initiative Organization (SDIO) is giving momentum to the community. The inclusion of the sensor-integration interests, in particular Defense Nuclear Agency (DNA), will continue. It was recommended that closer interactions with other environmental groups and product divisions within DoD be pursued. The question of DARPA involvement in the CIDOS community was raised but not resolved.

2. **Charter.** It was emphasized that a more formal statement of community purpose and function is needed than that which appears in the 1982 OUSDA/R&AT memorandum. The Steering Committee will formulate and submit a draft charter to OUSDA/R&AT before the next CIDOS conference. It was agreed that the present restriction of "no foreign nationals" on the CIDOS mailing list be retained. (The official CIDOS mailing list is maintained by the Air Force Geophysics Laboratory/Atmospheric Structure Branch.)

3. **Conference.** The periodic CIDOS conferences are the primary medium for information exchange of our community. The specific cloud-related topics dealt with at these conferences must change in response to user needs. It, therefore, was strongly urged (by IDA) that the Steering Committee meet more frequently in order to identify the more current and critical problems and to task appropriate sub-groups to work these and to report on them at future conferences. The following mechanics of the CIDOS conferences were considered:

   A. **Length.** The interest and level of attendance at CIDOS-88 indicates that a full 3-day conference is warranted. In particular, the first and second days should consist of oral/poster presentations. The morning of the third day should be scheduled for the actual workshop sessions and the afternoon for plenary and executive sessions.

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B. **Poster/Demonstrations.** Nearly all agreed that the poster sessions and demonstrations were an important part of CIDOS-88 and that they should be retained in future meetings. However, it was concluded that this type of presentation should be more formalized; specifically, times should be identified when the author(s) must be present at their poster/demonstrations.

C. **Workshops.** Most agreed that the topical workshops were of value but lacked structure. More formalized agendas put together by task-oriented subgroups could help in this regard. It was also suggested that these subgroups meet more than once each year.

D. **Next Meeting.** It was agreed that the next conference, CIDOS-89, will be hosted by the Naval Environmental Prediction Research Facility (NEPRF) in Monterey, California, in mid-October 1989.

APPENDIX A

CLOUD IMPACTS ON DOD OPERATIONS AND SYSTEMS
1988 WORKSHOP (CIDOS 88)
Naval Surface Warfare Center
White Oak, Maryland

18-20 October 1988

-AGENDA-

TUESDAY, 18 OCTOBER 1988

0730 - 0830 **REGISTRATION**

0830 - 0920 **INTRODUCTORY SESSION**

Chairman
Mr. Donald D. Grantham, Air Force Geophysics Laboratory, Atmospheric Sciences Division

Welcome
Capt R. G. Landrum, Deputy Commander, Naval Surface Warfare Center

Department of Defense Environmental Research
Col Ted S. Cress, Military Assistant for Environmental Science, Office of the Under Secretary of Defense for Acquisitions

Implication of Clouds in SDI Systems Planning
Dr. John H. Hammond, Director, Strategic Defense Initiative Organization, Directed Energy Office

0920 - 1030 **SESSION I - CLOUD IMPACTS ON SURVEILLANCE SYSTEMS**

Chairman
Col John Mill, USAF, Strategic Defense Initiative Organization, Sensors Office

Oral Presentations:

High Altitude Long Path Transmission in the MWIR
J. H. Schummers and G. G. Koenig

Effects of Clouds on the Electro-Optical Detection of Low Flying Air Vehicles from High Altitude or Space
E. Bauer, T. Paterson, and P. Albright

Cloud Radiance Simulation for Strategic Scenes
J. Jafolla, D. Anding, and F. Mertz

(U) Chemical Release Clouds as Countermeasures to Missile Acquisition and Tracking Sensors
M. R. Wohlers, M. Weinberg, and D. Munninghoff
(Presented in Classified Session III)

Relevant Poster Presentations/Demonstrations:

Cloud Impacts on the Airborne Optical Adjunct (AOA) During Testing in the Marshall Islands
1Lt R. F. Richfield, USA

Attaching the Boost Phase SBI Timeline with Clouds
D. Munninghoff and J. Hylden

Geophysical Data Base for Thrusted Vector Program
V. L. Griffin and M. J. Newchurch

Techniques to Categorize Cloud Imagery Data
J. Kristl, J. Schroeder, R. Haimes, and B. V. Kessler

1030 - 1100 **COFFEE BREAK**

1100 - 1230 **SESSION II - CLOUD IMPACTS ON STUDIES/ANALYSIS WARGAMING**

Chairman
Dr. G. Wayne Ullrich, Defense Nuclear Agency, Atmospheric Effects Division

Oral Presentations:

(U) A Description of Generic Nuclear War Environments for Generic Sensors Systems
G. W. Ullrich (Presented in Classified Session III)

(U) Battlefield Obscuration Factors
M. G. Heaps and F. E. Niles (Presented in Classified Session III)

RTNEPH (Real Times NEPH-analysis): A Description of the Model and Plans for the Future
1Lt T. M. Hamill, USAF

Pre-Strike Surveillance and Reconnaissance of Clouds
J. T. Bunting, R. P. d'Entremont, M. K. Griffin, and M. J. Kraus

Three-Dimensional Numerical Modeling of Smoke Injection from Large Fires in the Early Post-Nuclear-Exchange Environment
M. M. Bradley

Infrared Cloud Background Model
R. Haimes, J. Schroeder, M. Giles, L. Berk, D. Robertson, and B. V. Kessler

Relevant Poster Presentations/Demonstrations:

Synthetic Cloud Backgrounds for IR Scene Generation
J. Stets

Octree Encoding of Satellite Images for Fast Generation of Three Dimensional Cloud Scenes
T. A. Brubaker, G. Lee, T. Hoegland, T. H. Vonder Haar, and J. Behunek

Snow/Cloud Discrimination from Multispectral Satellite Measurements
Capt R. C. Allen, USAF

1230 - 1330 **LUNCH BREAK**

1330 - 1500 **POSTER/DEMONSTRATION SESSION A**

1330 - 1440 **SESSION III - (U) CLASSIFIED CIDOS-88 SESSION**

Chairman
Dr. Frank Niles, Director US Army Atmospheric Sciences Laboratory, Atmospheric Effects Division

(U) A Description of Generic Nuclear War Environments for Generic Sensors Systems
G. W. Ullrich

(U) Battlefield Obscuration Factors
M. G. Heaps and F. E. Niles

(U) Chemical Release Clouds as Countermeasures to Missile Acquisition and Tracking Sensors
M. R. Wohlers, M. Weinberg, and D. Munninghoff

(U) Thin Cloud Clearing; Physics and Issues
S. T. Amimoto, M. A. Kwok, and T. K. Tio

1440 - 1500 **COFFEE BREAK**

1500 - 1630 **SESSION IV - LIDAR DETECTION OF CLOUDS AND PARTICULATES**

Chairman
Dr. Paul F. Twitchell, Office of Naval Research, Applied Research and Technology Directorate

Oral Presentations:

Lidar Techniques for Observing the Morphological and Optical Properties of Cirrus Clouds
E. W. Eloranta

Lidar Measurements of the Troposphere and Middle Atmosphere
T. Wilkerson, U. Singh, C. Braun, M. Martins, B. Bloomer, G. Treacy, S. Yang, Z. Chu, and A. Notari

Airborne Lidar/Radiometric Characterization of High Altitude Clouds in Support of EO Sensor Performance Test Program
E. E. Uthe

Analysis of ER-2 Lidar Data for Cirrus Cloud Parameters
S. T. Shipley and J. D. Spinhirne

Relevant Poster Presentations/Demonstrations:

Characterization of Cirrus Clouds by High Spectral Resolution Lidar
C. J. Grund and E. W. Eloranta

Lidar Evaluation of Physical and Optical Properties of Aerosol Distributions for Atmospheric Effect Studies
E. E. Uthe

1630 - 1830 **POSTER DEMONSTRATION SESSION B - Ice Breaker**

WEDNESDAY, **19 OCTOBER 1988**

0800 - 0930 SESSION V - HIGH-ENERGY LASER/CLOUD INTERACTIONS

Chairman
Dr. Duane D. Smith, The Aerospace Corporation, Optical Physics Department

Oral Presentations:

Fundamental Aspects of Residual Refractive Turbulence after Laser Cloud-Clearing
D. D. Smith

Interactions of Laser with Realistic Atmospheric Clouds
J. Wallace, M. Cheifetz and J. Hummel

Vaporization and Recondensation Model for Laser-Irradiated Cloud Droplets
R. Morse and E. Caramana

Calculations of Cloud Channel Bleaching by Laser Irradiation and Subsequent Recondensation of Droplets
E. Caramana and R. Morse

Enhanced Cloud Clearing by Pulsed CO_2 Lasers
A. Waggoner and L. Radke

(U) Thin Cloud Clearing: Physics and Issues
S. T. Amimoto, M. A. Kwok, and T. K. Tio (Presented in Classified Session III)

Relevant Poster Presentations/Demonstrations:

Single Water Droplet Behavior During Laser-Induced Evaporation
R. P. Welle, S. T. Amimoto, and M. A. Kwok

A Cloud Chamber for Clearing Experiments by Pulsed CO_2 Lasers
L. Radke, A. Waggoner, V. Buonadonna, D. Dowling, and G. Quigley

A New Database of Ice Particle Size Spectra for Altitudes to 30,000 Feet
R. Jeck

Light Scattering by Thermal Diffusion from a Water Droplet Evaporated by Pulsed Irradiation
G. Sutton

Update on the Los Alamos National Laboratory Cloud Clearing Measurements
G. Quigley

0930 - 1020 **POSTER/DEMONSTRATION SESSION C**

COFFEE BREAK

1020 - 1230 **SESSION VI - CLOUD MODELING, PREDICTIVE SCHEMES AND DATA BASES**

Chairman
Dr. J. William Snow, Air Force Geophysics Laboratory, Atmospheric Sciences Division

Oral Presentations:

Advances in Cloud Prognosis at the Air Force Global Weather Central
Lt Col R. C. Whiton, USAF

Viewing Zenith Angle Dependence of Cloud Cover Derived From Coincident GOES-East and GOES-West Data
P. Minnis

A Multi-Station Set of Whole Sky Imagers and A Preliminary Assessment of the Emerging Data Base
R. W. Johnson and W. S. Hering

Semi-Markov Models for Cloudy and Cloud-Free Intervals
C. L. Medler and S. R. Finch

3-D Cloud Simulation
G. Y. Gardner

New Cloud Composite Climatologies Using Meteorological Satellite Imagery
E. M. Tomlinson, D. L. Reinke, C. F. Shih, and T. H. Vonder Haar

Cloud Signal Processing Techniques
J. Kristl, R. Haimes, J. Schroeder, and J. H. Schummers

Categorization of Clouds Using DMSP Imagery From the Fleet Numerical Oceanography Center Quadrilateralized Spherical Cube Satellite Data Base
A. K. Goroch

Relevant Poster Presentations/Demonstrations:

Hierarchical Validation of Complex Models: CFARC and CFLOS4D
S. R. Finch, R. G. Rasmussen, and C. L. Medler

Utilizing Bayesian Statistics to Make Cloud Cover Predictions
J. R. Hummel

Climatology of Cloud Statistics (C Cloud S)
J. H. Willand

A Model of Scattering of Millimeter Waves by Snow
J. A. Weinman

1230 - 1330 **LUNCH BREAK**

1330 - 1500 **SESSION VII - CIRRUS CLOUD CHARACTERIZATION, SIMULATION AND CLIMATOLOGY**

Chairman
Lt Col Kenneth E. Eis, USAF, 2nd Weather Squadron,
HQ Air Weather Service

Oral Presentations:

Overview of the Cirrus Forecast Problem
D. O'C. Starr

Cloud Models in LOWTRAN and FASCODE
E. P. Shettle, F. X. Kneizys, S. A. Clough, G. P. Anderson,
L. W. Abreu, and J. H. Chetwynd

Seasonal and Diurnal Changes in Cloud Statistics From VAS
D. P. Wylie

Cirrus Cloud CFLOS Prediction
J. R. Gillis, W. G. Tank, and C. J. Thomas

Climatology and Characterization of Tropical Cirrus Cloud Radiometric Properties
M. J. Newchurch, V. L. Griffin and J. S. Gothart

Relevant Poster Presentations/Demonstrations:

Characterization of Cirrus Clouds by High Spectral Resolution Lidar
C. J. Grund and E. W. Eloranta

A Radiometrically Calibrated Cirrus Image Simulation
A. Akerman, III and G. A. Hoffman, Jr.

Cirrus Clouds in the Southwest Pacific
K. C. Shrader

1500 - 1520 **COFFEE BREAK**

1520 - 1730 **WORKSHOP SESSIONS**

THURSDAY, **20 OCTOBER 1988**

0800 - 1000 **PLENARY SESSION**

1000 - 1230 **POSTER/DEMONSTRATION SESSION D (Optional)**

1230 - 1330 **LUNCH BREAK**

1330 - 1530 **EXECUTIVE SESSION**

APPENDIX B

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